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THE EFFECT OF ANESTHETICS ON LIVING CELLS

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The object of this research is to determine the effect of different anesthetics on several activities or properties of living cells, permeability, oxygen consumption, CO_2 production, photosynthesis, protoplasmic streaming and cell structure. Plant cells, Elodea as well as animal cells, Cassiopea, were used. Not all anesthetics had the same effect and the same anesthetic affected the same activity of a plant differently from an animal and affected different activities of the same cell differently. One correlation, however, was evident. All the anesthetics tried increased plant cell respiration and permeability. What might seem to be exceptions to this rule occurred under overdoses of the anesthetic and we were dealing with dead cells, which are outside the limits of this research.

All of the experiments were performed in thermostats at 30°. The Cassiopeas were kept in sea water, usually of alkaline reserve $= 0.0025\ N$ and $p_H = 8.2$ at the start, and the Elodea in a distilled water solution of $NaHCO_3$ of alkaline reserve $= 0.0025\ N$ and $p_H = 7.6$. At this alkaline reserve a change in p_H of 0.1 was produced by a change in CO_2 content per liter of 1.5 cc. By determining the change in p_H colorimetrically the production of CO_2 could be estimated. The oxygen consumed was determined by the Winkler method. The results were expressed in cc. of tenth normal thiosulphate for 100 cc. water in the Elodea experiments and as cc. of O_2 in the Cassiopea experiments. Since these data cover many pages even when condensed into tabular form, it is thought best to convert the results into percentages of the normal and summarize them. In the first place, higher concentrations of anesthetics evidently killed the cells and it was necessary to decide at just what concentration permanent injury occurred in order to separate such data from that concerning reversible changes characteristic of anesthesia. In the higher concentrations of anesthetics Elodea cells became irreversibly plasmolyzed (false plasmolysis), respiration and photosynthesis ceased, protoplasmic rotation stopped, the chloroplasts shrunk to a very small size and gave out some chlorophyll to the surrounding water, and there was a very sharp rise in the exosmosis of chlorides from the cells. On return to water, respiration did not commence again and the cell became the prey of bacteria. The cell might recover, however, after lowering of the rate of photosynthesis. Cessation of respiration seemed to be the best criterion of death in Elodea, but if the cells did not all die at the same time, the death of some cells could not be detected by this means. It seemed that a cell might live some time after protoplasmic rotation had ceased, but such cessation was an index that the lethal dose of anesthetic was approached, and it had the advantage of being observable in individual cells.

If the experiments in which protoplasmic rotation had ceased are omitted we may be confident that we are dealing with living cells and may summarize the data in the following table:

	PERCENTAGE CONCENTRATION	ABSORPTION OF O_2	ELIMINATION OF CO_2	EXOSMOSIS OF CHLORIDES	PROTOPLASMIC ROTATION	PHOTOSYNTHESIS	SIZE OF CHLOROPLASTS
Water..................		100	100	100	100	100	100
Alcohol................	0.05			100		94	100
	1.00	112	105	100	100	75	100
	1.50	135	125	150	105	62	99
	3.00	189	140	500	135	44	79
	6.00	163	175	2000	71	00	52
Ether..................	1.50	150	117	200	90	49	76
	3.00	186	133	1000	30	12	68
Chloroform.............	0.05	113	100	1500	130	47	91
Chloretone.............	0.05	117	150	150	71	100	100

In the above table the results with 6% alcohol might best be omitted. Some shoots of Elodea seem to be injured by the alcohol and it seems probable that some dead cells may have been used in each experiment. Since rotation did not cease but was only retarded in the cells observed, these data are included to avoid criticism. In some cases rotation stopped in 3% ether.

It may be seen from the table that all the anesthetics caused increased oxygen consumption and the greater the concentration of the anesthetic the more effective it was. There seemed to be some delay in the elimination of CO_2 as shown by successive time periods in the same experiment. This factor and the lesser sensitiveness of the method may be the reason cause for the failure of exact agreement between the CO_2 and the O_2 data. With marked increase in respiration there was also marked increase in exosmosis of chlorides as determined with the nephelometer. Protoplasmic rotation might be increased or decreased by the anesthetic, whereas photosynthesis was always decreased. In higher concentrations of the anesthetic the size of the chloroplasts was markedly reduced.

Since the effect of anesthetics on the conscious and automatic (rhythmical) centers in the central nervous system has been so thoroughly studied, it was decided to omit such data. Cassiopeas of about 15 cm. diameter were deprived of their automatic nerve centers by cutting off the margin of the bell. They were also deprived of the manubrium in order to eliminate the numerous mucous glands of that organ. The respiratory quotient was found to be about 95, and since the CO_2 data are less accurate than the oxygen data, only the latter are given. It was found that nerve conduction in the bell was abolished in one-half per cent ether. The jellyfish died at the end of an hour in 3% ether but by limiting the experiment to one hour, reliable data could be obtained at this concentration. Ether concentrations of one-half per cent, one per cent, two per cent and three per cent had no effect on the rate of respiration.

Owing to limited time it was thought best not to run through a long list of anesthetics in a hurried manner with no basis for hopes that a change in respiration rate might be observed, but to look for one which had been reported to change the rate. Carbon dioxide has been considered by many biologists as an anesthetic and used to anesthetize lower animals. I had previously observed that an increase in hydrogen ion concentration of the sea water might lower the respiration rate of Cassiopea, but had not determined whether this was due to H ions alone or to an associated increase in CO_2. The following experiments show that the metabolism is affected by CO_2 and not by increase in H ions without increase in undissociated CO_2 molecules.

Although Tortugas sea water contains about 44 cc. CO_2 per liter when estimated by adding acid and pumping it out, only a small fraction of this exists as CO_2 molecules in the water, most of it being in the form of HCO_3' and CO_3'' ions. If more CO_2 is added to the water a large increase in undissociated CO_2 molecules may be obtained. If HCl is added to the water, a limited increase in CO_2 molecules may be obtained, due to decomposition of carbonates and bicarbonates. An increase in H ions without increase in CO_2 molecules or even with decrease in CO_2 molecules may be obtained by adding enough HCl to neutralize the alkaline reserve, pumping out the CO_2 and adjusting the H ion concentration by minute additions of H_3PO_4. The results on relative rates of oxygen consumption after these methods of increasing H ions are as follows:

p_H	8.2	6.6	6.3	5.8	5.7	5.5
By adding CO_2	100	96	92	62	41	24
By adding HCl	100	98		70		
By adding HCl and removing CO_2	100			95		

In the above table the decrease of 5% in oxygen consumption after removing CO_2 is well within the limits of error of the method and is strikingly different from the decrease of 38% on adding CO_2 to obtain the same p_H without removal of CO_2. Therefore, the increased H ions are not responsible for the great fall in respiration after addition of CO_2.

In conclusion it seems evident that all anesthetics may not act in exactly the same way or exactly the same on both plants and animals, and that, whereas anesthetics may induce surface changes assumed to be associated with permeability, they are active on the inside of the cell as evidenced in shrinkage of chloroplasts. Anesthetics affect different cell activities differently. This may be due to effects on different cell structures : plasma membrane, chloroplasts and cytoplasm.

A GENERAL SINKING OF SEA-LEVEL IN RECENT TIME

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Among the causes of world-wide or "eustatic" shifts of sea-level are: appropriate crustal movements whereby the volume of the ocean basin is changed; delta-building and volcanic extravasation on the sea-floor, the displacement of sea-water not being compensated by crustal subsidence; volcanic addition of new water to the ocean; subtraction of water which becomes chemically bound during the alteration of rocks; glaciation on land, lowering sea-level by the abstraction of water from the ocean; deglaciation on land, raising sea-level; changes in the earth's center of gravity and in her speed of rotation. Numerous as these possibilities are, eustatic shifts at definite times and in definite amounts have not often been postulated by geologists. The proof of such a shift, either positive or negative, is not easy. The present note records some field facts suggesting the probability of a sinking of general sea-level to the extent of nearly 20 feet, during the Human period. The suggestion is published, not to express a fixed conclusion but to invite criticism by those familiar with shorelines in different parts of the world, for its testing is manifestly a world-wide problem. The matter is important because it affects judgment as to the reality of many so-called uplifts of land or sea-bottom, and because a close study of the latest shift of sea-level may help to systematize the criteria for earlier and larger eustatic shifts.

Nearly twenty years ago the hypothesis of a recent, negative movement of sea-level first presented itself to the writer while engaged in the correlation of post-Glacial elevated strands in Labrador and Newfoundland with those of Quebec. The highest strand mapped between Newfoundland and Nachvak Bay, 500 miles to the northwest, was found to be strongly warped, like the highest strand from Newfoundland to Massachusetts. On the other hand, the lowest emerged terrace along the shores of the Gulf of St. Lawrence was seen to be conspicuously level throughout a distance of 300 miles or more below Quebec City. This apparent uniformity of level prompted the question whether this particular strand had been abandoned by the waves because of a sinking of general sea-level. For lack of accurate leveling, correlation with the more closely studied, lowest